Rec'd PCT/PTO 11 MAR 2005
PCT/GB 2003 / 003996

10/527565

INVESTOR IN PEOPLE

The Patent Office

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

REC'D 23 OCT 2003
WIPO PCT

Best Available Copy

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed Stephen Hordley.

Dated 3 October 2003

Rule 4(1)

Form

Patents Act 1977
(Rule 16)

14[illegible]02 E748110-1 D00291
P01/7700 0.00-0221263.7

The Patent Office

1/77

THE PATENT OFFICE
G
13 SEP 2002
NEWPORT

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1. Your reference — SJC/DMC/P01896UK

2. Patent application number *(The Patent Office will fill in this part)* — 0221263.7 — 13 SEP 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   DKI Plast a.s.
   Erhvervsparken 7
   DK 4621 Gadstrup
   Denmark

   Patents ADP number *(if you know it)* — 8464125001

   If the applicant is a corporate body, give the country/state of its incorporation — Denmark

4. Title of the invention — Apparatus and method for improving the flow characteristics of a material to be injection moulded or extruded

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   Marks & Clerk
   49 Stoney Street
   NOTTINGHAM
   NG1 1LX
   ADP No. 00000018015

   Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body. — Yes

Patents Form ..

9. (ɹr the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	10
Claim(s)	1
Abstract	0
Drawing(s)	3 +3

0. If you are also filing any of the following, state how many against each item.

Priority documents	
Translation of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	One
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

I/We request the grant of a patent on the basis of this application.

Signature Lewis & Taylor

Date 12 September 2002

Name and daytime telephone number of person to contact in the United Kingdom

CHURCH, Simon John
(0116) 233 8181

ning

· an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or nunication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is ssary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents '977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an ication has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no tion prohibiting publication or communication has been given, or any such direction has been revoked.

DUPLICATE

TITLE: Apparatus and method for improving the flow characteristics of a material to be injection moulded or extruded.

The present invention relates to an apparatus and method for improving the flow characteristics of a material to be injection moulded or extruded.

The application of high frequency oscillations to a polymer is known to have an ameliorative effect on the melt flow characteristics of the polymer. Such an improvement would appear to have particular advantage in injection moulding processes, since there is evidence to suggest that the application of vibration to a thermoplastic moulding grade material improves the flow and distribution of the material in the moulding tool during the injection moulding process. Ultimately, the quality of the moulded article has also been shown to be improved. In fibre-reinforced injection moulding, it has been found that the application of vibration to a thermoplastic moulding grade material is effective in promoting both impregnation of the moulding grade material into the fibre reinforcement and wetting out (i.e. bonding) between the moulding grade material and the fibre reinforcement.

The use of ultrasonic vibration in the application of high frequency oscillations to a polymer during an injection moulding process is known to improve the melt flow characteristics of a polymer.

US 4500280 describes the use of an ultrasonic vibration aided feed device which consists of a body having a feed channel and an ultrasonic vibration generator connected to the body by an intermediate arm. In use, the feed device is positioned between the screw barrel and the nozzle of a standard injection moulding apparatus, such that the moulding material passes from the screw barrel into the moulding tool, via the feed channel. High frequency vibrations from the vibration generator are transmitted to the body through the intermediate arm, whereby moulding material passing through the feed channel is indirectly subjected to vibration. The use of vibration generators having a frequency equal to 20kW or 40kHz were found to be satisfactory

in improving the melt flow characteristics of the moulding material. However, in order to incorporate the feed device between the screw barrel and the nozzle, the whole injection moulding apparatus has to be reconfigured.

US5885495 describes a purpose-built injection head for an injection moulding apparatus, which includes an assembly for applying vibration to a moulding grade material. The assembly includes a chamber between the screw barrel and the nozzle of the injection head, wherein the chamber has an inlet valve and outlet valve for controlling the passage of material into and out of the chamber. In use, with the outlet valve in a closed position, the inlet valve is opened to allow a volume of material to enter the chamber. The inlet valve is then closed and the chamber is subjected to ultrasonic vibration to improve the melt flow characteristics of the moulding grade material. After a predetermined period of vibration, the outlet valve is opened to allow the moulding grade material to be injected through the nozzle. Since the vibration is not applied during the injection phase of the moulding process, the overall process times for the apparatus require significant alteration from standard injection moulding cycle times. Hence, the productivity of the injection moulding apparatus is reduced. Further, since the injection head differs from a typical injection head for a standard injection moulding apparatus, the injection head is not retrofittable to the existing apparatus for an injection moulding company.

It is also known to apply ultrasonic vibration directly to the screw of the screw barrel of an injection head, as described in US 6203747, to apply vibration to the moulding material whilst in the screw barrel prior to injection into the moulding tool. However, this also involves the manufacture of a purpose-built injection moulding head and is therefore not retrofittable to the existing apparatus for an injection moulding company.

Further, US 5017311 describes the application of high frequency vibration to the whole of the mould cavity of a moulding tool by an ultrasonic vibration device attached to the moving half of the mould cavity. The apparatus allegedly provides a remarkable improvement in the apparent fluidity of the moulding material at a vibration frequency of 19.15 kHz. As this involves the vibration of the whole moulding tool, a specially designed injection moulding apparatus is

required. Alternatively, the moulding material is vibrated through localised vibration of the tool cavity, once the mould cavity has been filled, thus increasing the moulding cycle times and, hence, reducing the productivity of the injection moulding apparatus.

It is an object of the invention to reduce, or substantially obviate, the disadvantages referred to above.

According to the broadest aspect of the present invention, there is provided an apparatus for improving the flow characteristics of a material to be injection moulded or extruded, comprising a flow path through which a material to be injection moulded or extruded passes in use, and a vibration device for directly vibrating material in the flow path.

In a preferred embodiment, the vibration device comprises means which extend at least partially into the flow path for directly vibrating material in the flow path.

Preferably, the vibration device consists of an ultrasonic probe.

According to a further aspect of the invention, there is provided a method for improving the flow characteristics of a material to be injection moulded or extruded, in which a volume of material is injected or extruded through a flow path in an injection moulding or extrusion apparatus whilst being directly subjected to vibration.

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-section through part of an injection moulding apparatus for use in accordance with a first embodiment of the invention, showing the mould tool in an open position, prior to injection;

Figure 2 is a view similar to Figure 1 with the tool closed, prior to injection;

Figure 3 is a view similar to Figure 2, during injection;

Figure 4 is a view similar to Figure 1, with the tool in an open position, after injection; and

Figure 5 is a schematic cross-section through part of an extrusion apparatus for use in accordance with a second embodiment of the invention.

Referring to Figures 1 to 4, an injection moulding apparatus, indicated generally at 10, includes a moulding tool 12 having a mould cavity indicated at 14. The apparatus 10 further includes a barrel 16 of known construction, having a screw 18 which is movable between a back position, as shown in Figures 1, 2 and 4, and a forward position as shown in Figure 3.

The moulding tool 12 consists of a fixed part 20 which in use remains stationary relative to the barrel 16, and a moving part 22 which is movable relative to the fixed part 20, between an open position as shown in Figures 1 and 4, and a closed position as shown in Figures 2 and 3. The mould cavity 14 has four mould compartments 24, only two of which are visible in Figures 1 to 4, for producing four moulded articles, two of which are indicated at 26 in Figure 4.

The fixed part 20 of the moulding tool 12 includes four injection gates 28, one for each mould compartment 24, only two of which are visible in Figures 1 to 4, through which thermoplastic moulding grade material passes into the mould cavity 14 during the injection moulding process, as will be described below.

The fixed part 20 has an inlet channel 30 and a central chamber 32, through which thermoplastic moulding material flows from the barrel 16 to the moulding tool 12, in use.

An ultrasonic vibration device, indicated generally at 34, is mounted to the upper end of the fixed part 20 by a frame 36. The ultrasonic vibration device 34 consists of an ultrasonic probe, hereinafter referred to as the sonotrode 38, which extends from the frame 36 into the central

chamber 32 to a depth below the inlet channel 30. Hence, the sonotrode 38 extends at least partially into the melt stream of the thermoplastic moulding material, in use.

A sealed seating ring 40 is provided in the central chamber 32, for centrally locating the sonotrode 38 in the chamber 32 and for preventing moulding material from escaping up through an open end of the chamber 32. The seating ring 40 is manufactured from a suitable thermoplastic or ceramic material, to prevent interaction with the sonotrode 38 during vibration, which might cause the seating ring 40 to weld to the sonotrode 38, to reduce the risk of fracture of the sonotrode 38 in use.

A converter 42 is mounted at the upper end of the ultrasonic vibration device 34, for converting electrical energy supplied to the ultrasonic vibration device 34 from an auxiliary power source, not illustrated, into high frequency mechanical vibration. A booster 44 is provided on the ultrasonic vibration device 34 beneath the converter 42, for boosting the signal from the converter 42 to the sonotrode 38.

In use, the mould cavity 14 and the channel 30 and the chamber 32 in the first part of the tool 20 are heated to temperatures suitable for the processing of the particular moulding material being used. This is achieved by using a modified hot runner system to keep the thermoplastic molten prior to injection into the cooler mould cavity.

Operation of the moulding apparatus 10 during a moulding cycle will now be described. For the purposes of description, it is assumed that a first moulding cycle has already been carried out and the injection gates 28, central chamber 32 and inlet channel 30 of the fixed part of the moulding tool 12 are at least partially filled with thermoplastic moulding material. A volume of material V1 is required to fill the injection gates 28, central chamber 32 and inlet channel 30 of the fixed part of the moulding tool 12.

A second moulding cycle starts with the moulding tool 12 in the open position having the screw 18 in the back position, as shown in Figure 1, and the ultrasonic vibration device 34 in a

deactivated condition. With the screw 18 in the back position, a melt reservoir of thermoplastic moulding material is present in the barrel 16, having a volume V2. A volume of material V3 is receivable in the compartments 24 of the mould cavity 14 when the moulding tool 12 is in the closed position shown in Figures 2 and 3, wherein V2 is greater than V3 and V1 is not greater than V2. The difference in volume between V3 and V2 provides a cushion for the volume of material in the moulding tool 12 after injection, to maintain pressure on the volume of material in the moulding tool 12 after injection, i.e. when the screw 18 is in the forward position shown in Figure 3, as will be described below.

The moving part 22 of the moulding tool 12 then moves to the closed position shown in Figure 2. Once the moulding tool 12 is closed, the ultrasonic vibration device 34 is activated for a predetermined period, prior to an injection phase commencing. When ultrasonic vibration device 34 is activated, the sonotrode 38 vibrates in the longitudinal direction at a fixed frequency within the central chamber 32. Hence, during vibration of the sonotrode 38, at least a portion of the moulding material present in the fixed part 20 is affected by the vibration energy of the sonotrode 38.

Whilst the ultrasonic vibration device 34 is still activated, an injection phase commences, in which the screw 18 moves towards the forward position shown in Figure 3. As the screw 18 moves forward, the thermoplastic moulding material in the barrel 16 is injected into the fixed part 20, through the inlet channel 30. The pressure of the material entering the fixed part 20 from the barrel 16 forces the thermoplastic moulding material which is already present in the injection gates 28, central chamber 32 and inlet channel 30 into the mould cavity 14. As the screw 18 reaches the forward position, the mould cavity 14 fills until no further moulding material may pass through the injection gates 28. The volume of material remaining in the screw barrel 16 is continuously pushed into the fixed part 20, until the screw 18 finally reaches the forward position shown in Figure 3. The screw barrel is maintained in the forward position shown in Figure 3, until the material in the tool cavity has solidified, to maintain pressure on the volume of material in the moulding tool.

Hence, during the injection phase, the moulding material passing through the chamber 32 is affected by the vibration energy from the sonotrode 38.

At a predetermined stage in the injection phase, for example at the point where the mould cavity 14 becomes filled with moulding material, the ultrasonic vibration device 34 is switched off. Once sufficient cooling of the moulding material has occurred, the screw 18 is returned to the back position shown in Figure 4, to prepare a melt reservoir of thermoplastic moulding material in the barrel 16 for the next moulding cycle. The moving part of the moulding tool is then moved to the left as viewed, to the open position shown in Figure 4, and the moulded articles are ejected.

During the above-described period of activation of the ultrasonic vibration device 34, the vibration energy transmitted through the sonotrode 38 is transferred to at least a part of the volume of moulding material simultaneously present in the central chamber 32. This has the effect of improving the melt flow characteristics of the moulding material as illustrated in the following example.

Example

Initial trials were carried out using a general-purpose Polypropylene (PP) injection moulding grade material to see if the ultrasonic vibration device had an influence on the flow performance of the material. An injection moulding apparatus, substantially as described with reference to Figures 1 to 4, was set up with the full injection shot capacity in the barrel but the injection time was set to mould a short shot volume to partially fill a flat plaque component of approximately 25 g in weight.

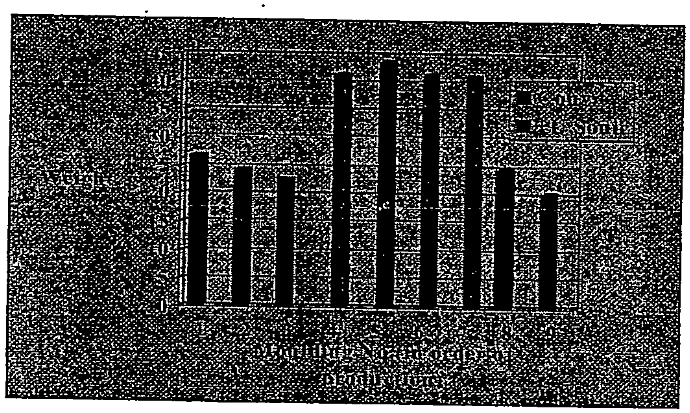
A first set of mouldings was produced without the use of the ultrasonic vibration device, which produced short shot mouldings having a component weight of approximately 25g, as anticipated.

A second set of mouldings were then produced using the same shot volume and injection conditions but with the ultrasonic vibration device activated prior to the start of the injection cycle and during filling of the mould cavity, substantially as described above. The resultant mouldings were much larger than the first set and had a final weight of approximately 42 g.

A third set of mouldings was then produced without the use of the ultrasonic vibration device, which produced short shot mouldings as had been achieved in the first set of mouldings.

The results of the trials are presented in the following graph.

Graph showing effect of Ultrasonic vibration on polymer flow.



Hence, it can be seen that for the same injection time, the weight of each moulding achieved using the ultrasonic vibration device significantly increased. This suggests that the use of the ultrasonic vibration device significantly improves the melt flow characteristics of the moulding grade material, to promote increased flow through the moulding tool.

It will be appreciated that the above described ultrasonic vibration device can be operated on a single gate moulding tool.

The invention also has application for extrusion grade materials, as described below.

An extrusion apparatus for use in accordance with a second embodiment of the invention is shown in Figure 5, indicated generally at 50. The extrusion apparatus 50 consists of an extruder barrel 52 and a modified die block 54. The modified die block 54 has a flow channel 56 for passage of thermoplastic moulding material from the extruder barrel 52, which includes a central chamber 58.

An ultrasonic vibration device 60, similar to that described above, is mounted to the modified die block 54, so that the sonotrode 38 extends into the chamber 58 to at least partially pass into the extrusion path for extrusion grade material passing though the flow passage 56, i.e. at least partially into the melt stream.

A sealed seating ring 40 is used to centralise the sonotrode 38 in the chamber 58 and prevents material from escaping through the open upper end of the chamber 58.

The ultrasonic device 60 is substantially the same as that described above in relation to Figures 1 to 4 and so the operation and construction of the device will not be described again in significant detail. However, where necessary, common reference numerals are used.

During extrusion of material from the extruder barrel 52, the ultrasonic vibration device 60 is activated to improve the melt flow characteristics of the extrusion grade material as it passes through the chamber 58. The ultrasonic device 60 may be activated continuously or discontinuously, depending on the effect required on the produced article. During periods of activation of the ultrasonic vibration device the material present in the chamber 58 will be affected by the vibration of the sonotrode as discussed above.

Hence, the described embodiments of the invention provide ultrasonic vibration through the use of a sonotrode at least partially within the melt stream of an extrusion or injection moulding grade material, to improve the flow characteristics of the material.

The ultrasonic vibration device of the described embodiments can be retrofitted to existing

extrusion or injection moulding apparatus, without significantly altering the configuration of the existing apparatus. Further, the ultrasonic vibration according to the described embodiments of the invention can be applied without significantly altering the process times/mould cycle settings.

Although the invention has been described with reference to a mould tool having four compartments in the tool cavity, the invention has application in a mould tool having any number of compartments in the tool cavity, for example a single compartment, two compartments, or 10 compartments, as desired.

Claims

1. An apparatus for improving the flow characteristics of a material to be injection moulded or extruded, comprising a flow path through which a material to be injection moulded or extruded passes in use, and a vibration device for directly vibrating material in the flow path.

2. An apparatus as claimed in claim 1, in which the vibration device comprises means which extend at least partially into the flow path for directly vibrating material in the flow path.

3. An apparatus as claimed in claim 1, in which the vibration device consists of an ultrasonic probe.

4. A method for improving the flow characteristics of a material to be injection moulded or extruded, in which a volume of material is injected or extruded through a flow path in an injection moulding or extrusion apparatus whilst being directly subjected to vibration.

Figure 1

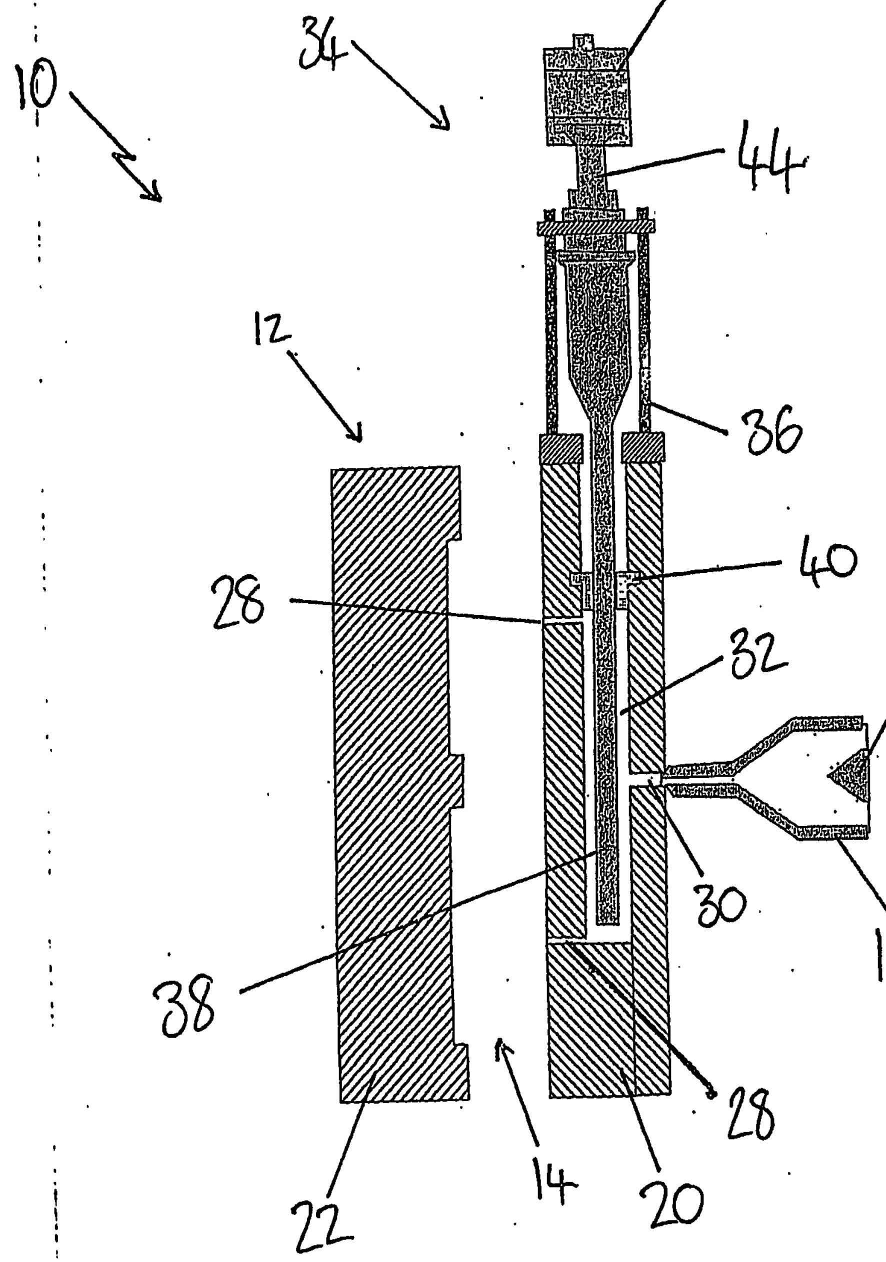


Figure 2

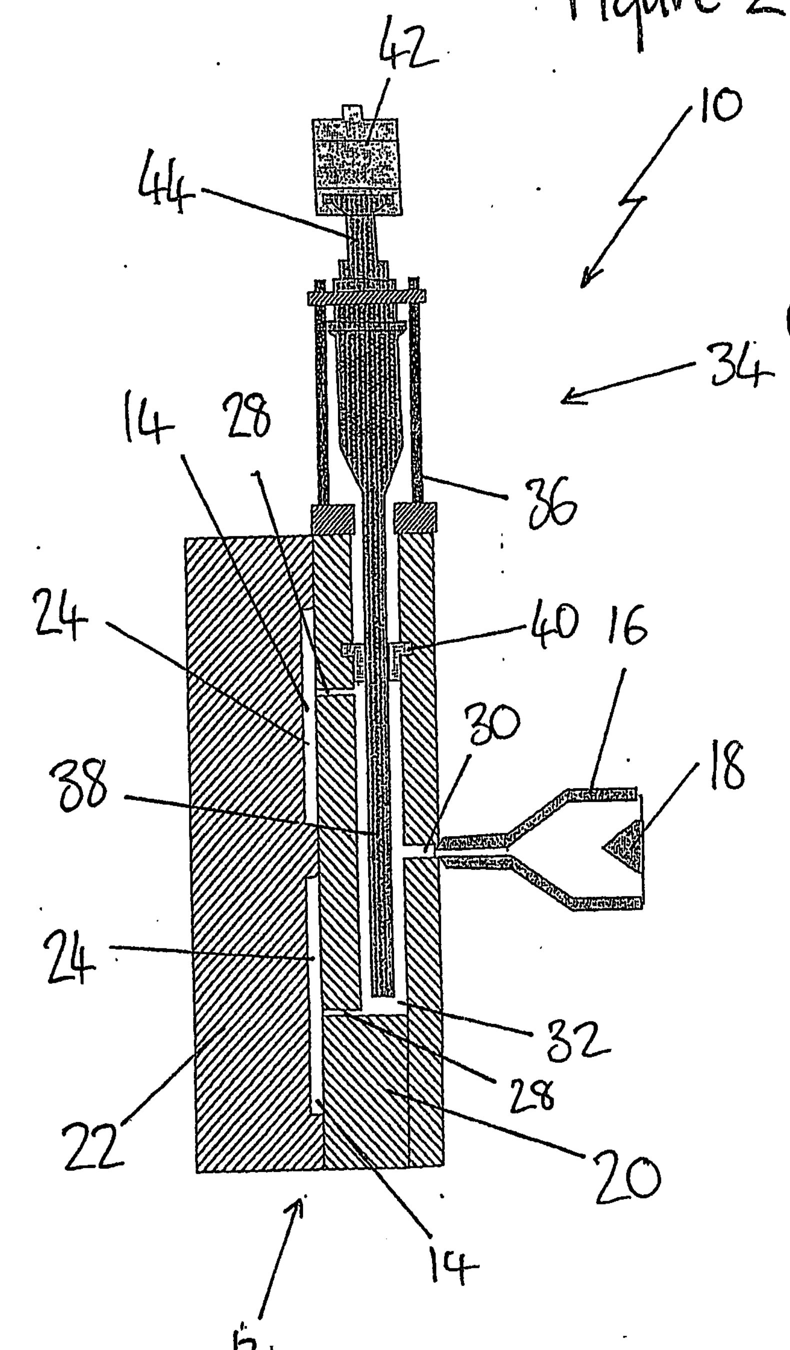


Figure 3

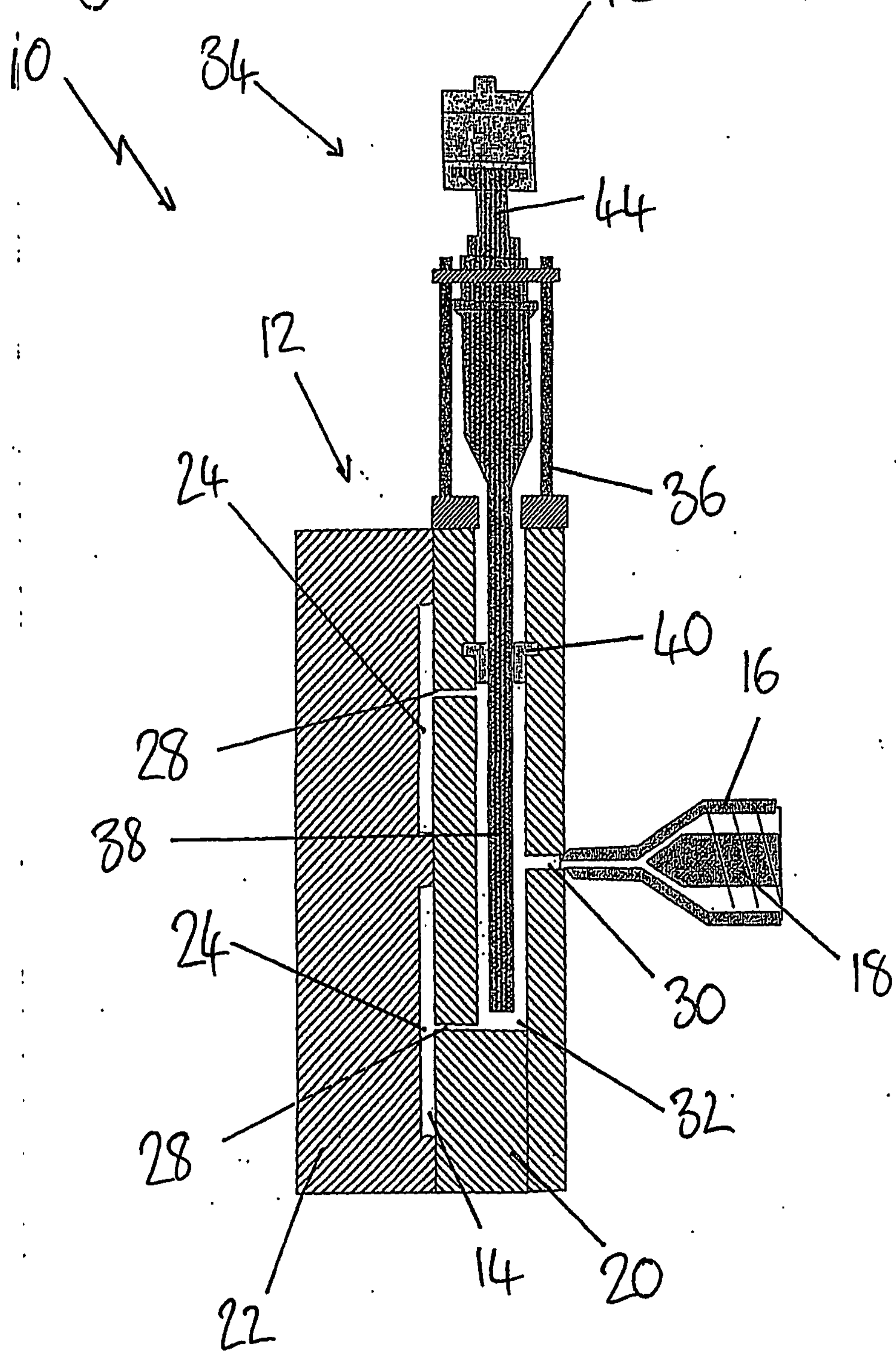


Figure 4

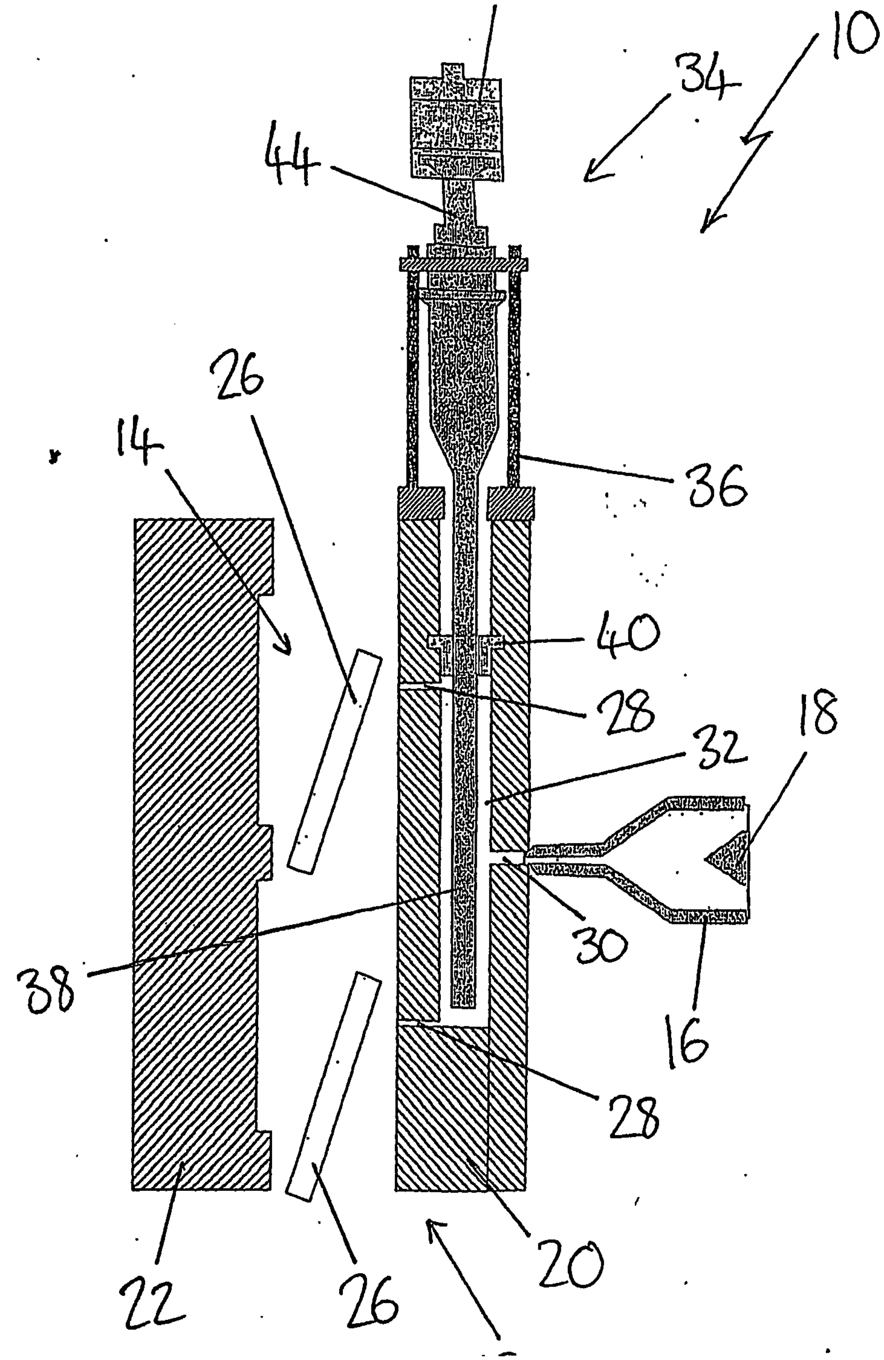


Figure 5